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A New Resource Allocation Algorithm in OFDM System

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Abstract----In this paper, we present an improved power allocation algorithm that maximizes the total capacity in the OFDM system. The improved allocation algorithm is based on the existing water-filling algorithm. To reduce the computational complexity in calculating water-filling level and make up for the shortcomings of the equally distributed algorithm, we propose the improved allocation algorithm where some subcarriers adopt water-filling algorithm and others take equally distributed algorithm. Besides, we will introduce two parameters M and V in the equally distributed algorithm to increase the system performance. Simulation has been done to prove that our algorithm has the performance better to the existing water-filling algorithm and has the lower computational complexity than it. Our algorithm also can be used in actual systems.

Keywords---OFDM; power allocation; water-filling algorithm; equally distributed algorithm

1. Introduction

It is known that reliable and high-rate data communications for the wireless multimedia environment are essential. However, due to the time dispersive nature of the wireless channel, high-rate data communications are significantly limited by inter symbol interference (ISI). Because of its high spectral efficiency against frequency-selective fading effects and ISI, orthogonal division multiplexing(OFDM) modulation has become a promising technique for the next generation of wireless communication systems[1],[3]. OFDM is one of the widely used multicarrier systems. The principle of the OFDM technique is to divide the available bandwidth into N orthogonal sub channels. In addition, we can completely eliminate the ISI by adding a cyclic prefix (CP) to each OFDM symbol. When CP is longer than the channel length, the channel tends to be circular [2].

Owing to the advantage of the OFDM system, recently there appear some algorithms to resolve the resource allocation problem in OFDM systems [4]. Among these, water filling theorem is very popular although it has the disadvantage of computational complexity. In this paper we present an improved water filling algorithm based on the classic water filling theorem. As we know, when the SNR reaches a certain level, there is little difference between water filling algorithm and equally distributed algorithm in the performance. In order to reduce the computational complexity in calculating water-filling level in the water filling algorithm, we propose a simple method where some subcarriers adopt water filling algorithm to allocation power and others take equally distributed algorithm. Besides, we will introduce two parameter objects in the equally distributed algorithm to increase the system performance.

2. System Model and Problem Rmulation

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As for resource allocation in OFDM system, when we prepare to allocate subcarrier and power for users, we must ensure the balance between users’ fair performance and users QoS performance [6]. Once the subcarrier allocation has been established, the power allocation for each user can be determined, which aims at maximizing the total capacity and doesn’t affect the users fair performance. So the power allocation plays an important role in the OFDM system.

Because the total capacity is the sum of the capacity of each subcarrier in the OFDM system, using the notation in Table 1, the total capacity problem can be formulated as follows:

$$C = B/N\sum_{n=1}^{N}\log_2(1+\frac{\alpha_\text{n}^2 P_n}{N_O B/N}) \tag{1}$$

TABLE 1 GENERAL NOTATION

Notation	Description
N	The number of carriers
B	the system bandth.
αn	Gain of subcarrier n
P_n	The transmitted power
N_o	Single power strum of additive noise

Then the capacity is the Shannon Capacity. In deed, with the constraint of the total power, the capacity problem can be reformulated as follows:

$$C = \max B/N\sum_{n=1}^{N}\log_2(1+\frac{\alpha_\text{n}^2 P_n}{N_O B/N}) \tag{2}$$

Subject to:

$$P_T = \sum_{n=1}^{N} Pn <= P$$

$$\sum_{n=1}^{N} Pn >= 0 \qquad \forall n \tag{3}$$

The basic idea in the water-filling algorithm is to assign more power to subcarriers that experience higher channel gain, while assigning little or no power to the subcarriers suffering from low channel gain [7]. First, we will introduce the basic idea of the water-filling algorithm.

According to formulation (2), we make use of the Lagrange to make the Lagrange function. The allocated power can be formulated as follows:

$$Pn = \left[\frac{1}{\beta} - \frac{1}{T_n}\right]^+ \tag{4}$$

where β is the water level. To get the suitable β, the iterative water-filling algorithm has to do multiple iterations, which makes the high computational complexity. To reduce the computational complexity, the paper gives an improved water-filling algorithm.

3. The Discription of the Improved Waterfilling Algorithm

As we mentioned, to reduce the computational complexity in calculating water-filling level and make up for the shortcomings of the equally distributed algorithm, we propose a simple method where some subcarriers adopt water-filling algorithm to allocation power and others take equally distributed algorithm. Besides, we will introduce two parameters M and V in the equally distributed algorithm to increase the system performance.

In this paper, we assume N subcarriers indexed by n $\in$ {1, 2…..N} and the total transmitted power is given as P. The introduced parameter M represents the number of subcarriers which adopt equally distributed algorithm. M ranges from 0 to N. when its value is 0, then the power allocation algorithm is just water-filling algorithm, while its value is N, the power allocation algorithm is equally distributed algorithm. So the value of M plays an important role in the power allocation. The parameter V determines the power allocated to the subcarriers which adopt equally distributed algorithm. Its range is [0, 1]. When all the subcarriers adopt equally distributed algorithm, the power allocated to each subcarrier is P/N. In this paper, we certainly do not allocate P/N to the subcarriers adopting equally distributed algorithm, while we will allocate (P/N)*V, where V is a weight in the range of [0, 1]. We can regulate the value of the V to make a better system performance.

The two parameters above are key to the improved water-filling algorithm. No matter we change either of them, it will have an impact on the system performance. It not only reduces the computational complexity of water-filling algorithm but also avoids the dissatisfied characters of the equally distributed algorithm.

4. Simulation Results

In this section, we introduce some numerical results for the subcarrier and power allocation algorithms introduced in this paper. We consider 64 subcarriers in the simulation. Firstly, improved water-filling algorithm, existing water-filling algorithm and equally distributed algorithm will be compared under the same conditions.

Figure 1 shows the results of the comparison of three algorithms. It is clear that improved water-filling algorithm has the maximum capacity while equally distributed algorithm is the worst.

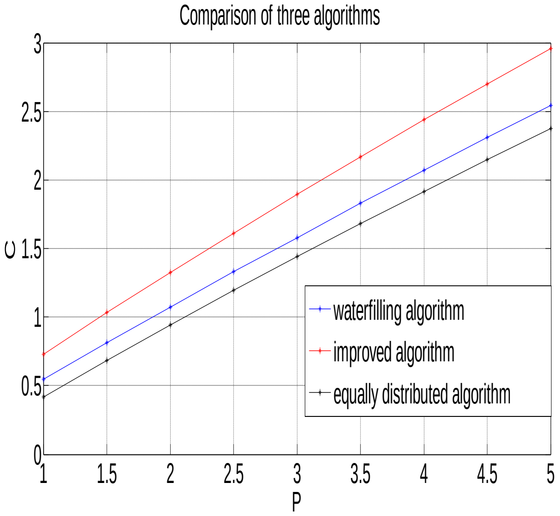

Fig.1 Comparison among three algorithms when N=64, M=3 and V=0.6

In addition, given a fixed M, we will compare the system capacity based on different V. Theoretically, if the value of V is too small, some subcarriers will get less power while others more power, which may cause power allocation lose equity among the subcarriers.

Figure 2 shows the results when v=0.1, v=0.3, v=0.6 and v=0.8. From the figure, we can know that v=0.6 is the best.

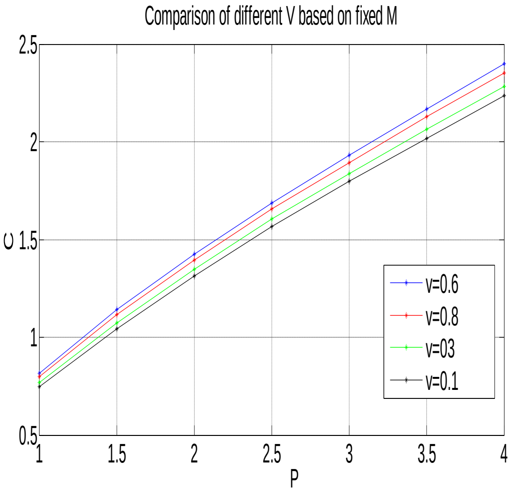

Fig2 Comparison among different V when N=64 and M=3.

At last, given a fixed V, we will compare the system capacity based on different M. M is neither too large nor too small， we must select an appropriate value.

Figure 3 shows the results when M=2, M=3 and M=6. We can conclude that the appropriate value of M is 3.

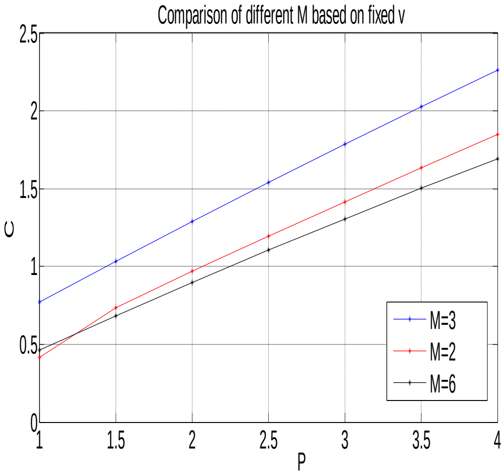

Fig3 Comparison among different M when N=64 and V=0.6.

5. Conclusions

In this paper, we studied the problem of OFDM subcarrier and power allocation. An improved water-filling algorithm was introduced in detail, where the parameter objects M and V are the important points. The improved algorithm significantly reduces the computational complexity of the original allocation problem and considers the fairness among subcarriers, thereby making the algorithm suitable for real time systems.

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